## The United Arab Emirates Unified Aerosol Experiment (UAE²)

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**Introduction:** The Southwest Asian region surrounding the Arabian Gulf is one of the most difficult environments in the world to characterize, model, and monitor. Frequent dust storms, high pollution levels, and complex flow patterns dominate the region. The atmosphere is heavily impacted from air masses from five subcontinents (Central-North Africa, Europe, Arabian Peninsula, Central Asia, and the Indian Subcontinent), and at the same time influenced by very strong micro to mesoscale circulations that form around the hot deserts, warm waters, and mountain ranges. Previous generations of remote sensing systems and meteorology models have had tremendous difficulty coping with the bright, hot, and variable desert landscape as well as the shallow and warm coastal waters. The interests in Southwest Asia are obvious for military and civilian research communities. The poor visibility and complicated meteorology converge to disrupt operations in Iraq and Afghanistan as well as navigation and air operations in the Arabian Gulf. The Arabian Gulf region is an excellent natural laboratory for the study of micrometeorology, air-sea interaction, atmospheric chemistry, radiative transfer, cloud microphysics, aeolian processes, climate change, and the development of atmospheric remote sensing and modeling systems in complicated environments. The research program described here was developed to address these topic areas and is an excellent link between DoD and civilian research interests.

**The UAE² Campaign:** Beginning in the summer of 2004, the Marine Meteorology Division led the United Arab Emirates Unified Aerosol Experiment (UAE²), funded by NASA, ONR, and NRL, to study the atmospheric phenomenology of Southwest Asia and the Arabian Gulf. Hosted in country by the UAE Office of His Highness the President, Department of Water Resource Studies (DWRS, now the UAE Department of Atmospheric Studies), the eight-country, 50-member science team focused on the mesoscale meteorology, aerosol microphysics, and remote sensing of Southwest Asia. The deployment was organized to intensely monitor the strong gradients in atmospheric parameters over the entire southern Gulf region (Fig. 9). Included were 2 research aircraft, 15 satellite sensors, 5 atmospheric models, and 15 AERONET Sun photometers—the densest such network ever deployed. The UAE DWRS provided data from 52 meteorological stations, the only surface mesonet in Southwest Asia. The mission also included the deployment of NRL's Mobile Atmospheric Aerosol and Radiation Characterization Observatory (MAARCO, Fig. 9) at a coastal site. At MAARCO, a complete set of meteorology, aerosol, and radiation information was obtained during the experiment. A secondary station was deployed in the interior

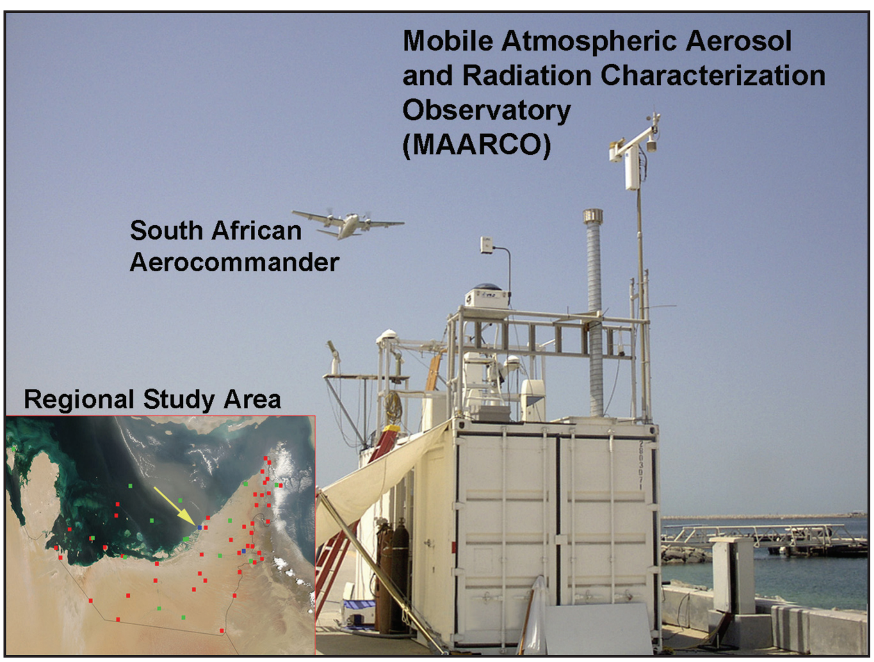


**FIGURE 9**
The NRL MAARCO with the South African Research Aircraft performing an overpass. Also included is a map of the study region with locations of DWRS weather (red), AERONET Sun photometer (green), and super sites (blue). MAARCO is indicated by a yellow arrow.

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desert by NASA to study radiative transfer. A complete description of the first year's study accomplishments can be found in Ref. 1.

**Significant Advances in Aerosol Chemistry and Meteorology by NRL:** While large dust events do occur regularly in Southwest Asia, one of our primary findings was that the smaller mesoscale dust events and atmospheric pollution had the most widespread influence on the atmospheric radiative balance or visibility. Consider Fig. 10, where the Coupled Ocean Atmosphere Mesoscale Prediction System (COAMPS®) surface wind fields for September 12, 2004, are overlaid on the NRL MODIS Dust Enhancement Product.[2] The wind directions clearly show the area where the easterlies interact with the regional southwest monsoonal winds over the Arabian Gulf causing a large convergence zone to form, as evidenced by the region of heavy dust concentration (red shade). On this day, aircraft measurements over the Gulf of Oman and Arabian Gulf revealed the westward advection of high pollution content from the Indian subcontinent into the Gulf of Oman, with associated surface visibilities below 2 km. Similarly, oil platforms in the Arabian Gulf (lower right panel in Fig. 10) also contributed to significant pollution events within the region.

Case studies such as these have led us to a principal area of study: how do atmospheric, land, and ocean scales on the order of kilometers impact the mesoscale and in turn the larger synoptic scale? Indeed, we found that close attention to these smaller scale events is of importance in trying to model aerosol budgets, lifecycle, and impacts. Figure 11 provides an excellent illustration of how NRL satellite-derived products assist in small-scale research efforts. In this example, the Defense Meteorological Satellite Program/Operational Linescan System (DMSP/OLS), METEOSAT-5/IR, Terra/Moderate-resolution Imaging Spectroradiometer

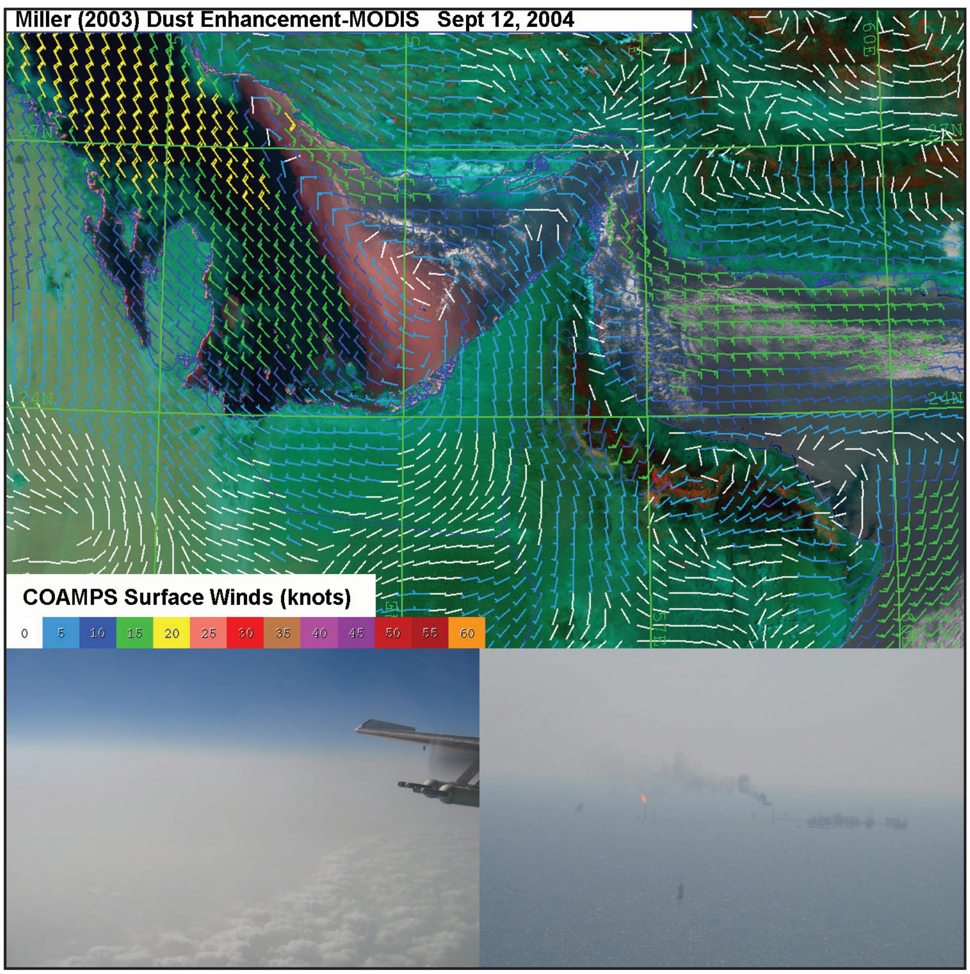


**FIGURE 10**
NRL Dust enhancement product with COAMPS® surface winds overlay for the September 12, 2004, case. Overlaid is the research aircraft flight track for this day. Here we see two air masses colliding, where pollution from the Indian Subcontinent meets dust from Iraq. Lower left, view of this dust event from a 10,000-ft altitude. Lower right, hazy conditions from pollution in polluted region of the Arabian gulf.

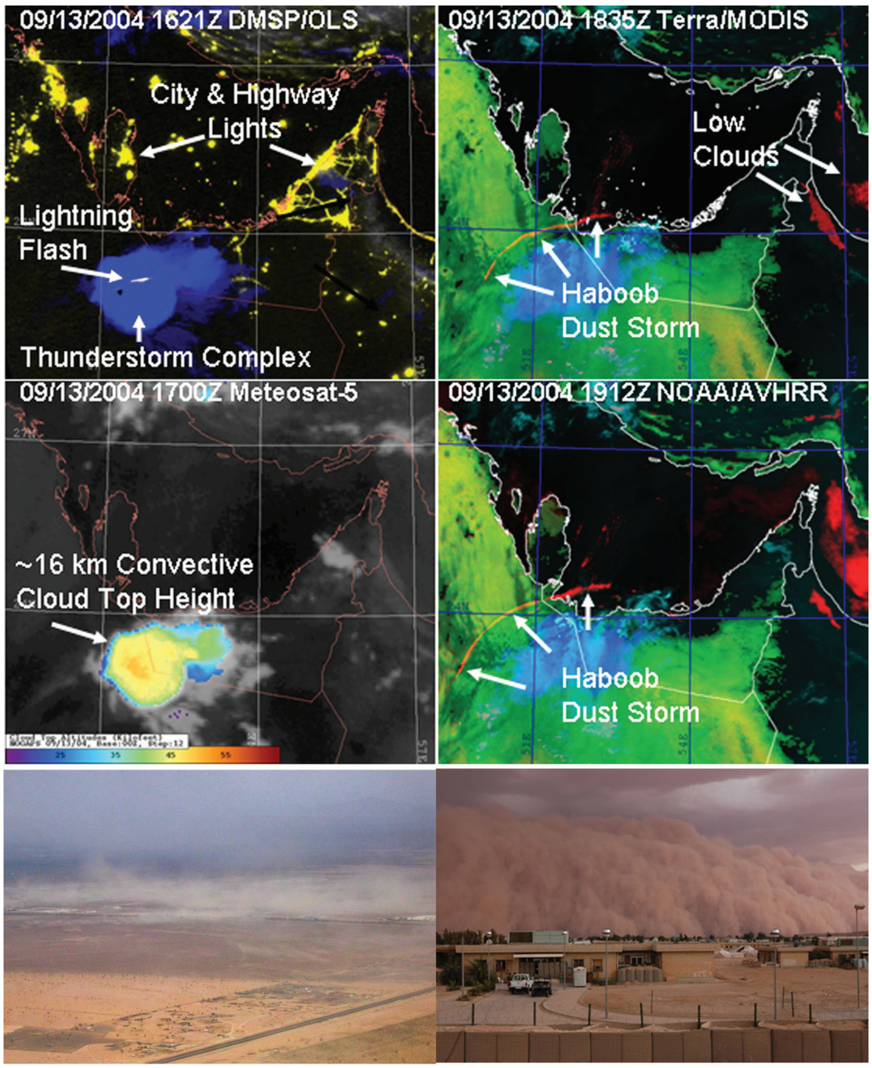


**FIGURE 11**
Multisensor panel of the observation of a massive Haboob event for September 13, 2004.[3] In this case, the OLS shows storm electrification (proxy for intensity), Meteosat-5 shows substantial vertical development and provides high-temporal resolution, and the MODIS/AVHRR sensors provided enhancement of the dust front itself. Lower left, a Haboob event in its formation in the interior of the UAE. Lower right, a massive Haboob event in Iraq. (Photograph by Sgt. Shannon Arledge, U.S. Marine Corps Story Identification No. 2005426134811.)

(MODIS), and National Ocean and Atmospheric Administration/Advanced Very High Resolution Radiometer (NOAA/AVHRR) captured a massive dust event that formed within the outflow of a thunderstorm (called "Haboobs"). The NRL dust enhancement products (upper and middle right panels) clearly illustrate the dust front ahead of the thunderstorm. Photographs within the lower 2 panels dramatize the onset of the Haboobs; these events occurred with frequency during $UAE^2$. In combination with other mesoscale flows, such as the strong sea-land breezes and orographically induced winds, haboobs ultimately manifested themselves at a scale once thought to be dominated by much larger-scale synoptic patterns.

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